CHARACTERIZE THE MECHANICAL PROPERTIES OF SELECTED TYPE OF COASTAL PLASTIC WASTE

MOHD HAFIZ BIN ISMAIL

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Chemical Engineering

Faculty of Chemical and Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG

JANUARY 2012

ABSTRACT

Human are heavily dependent on the sea for economic and sources of high-protein food. In the past 10 years, coastal plastic pollution has extremely increased and this circumstance may affect human healthiness, difficulties to marine activities, and decreasing of quality of seawater. Not only plastic is made from a non-renewable resource, but it is generally a non-biodegradable material which made biodegradation process is very slow. Due to that recycling of coastal plastic waste is one of possible measures to be taken to tackle this issue. However, because of long exposure to the seawater and direct sunlight, the mechanical properties of coastal plastic waste would differ from the commercial plastic. The objectives of this study are to characterize mechanical properties of coastal plastic waste and compare the mechanical properties of coastal plastic waste with the commercial plastic and to analyse the differences of mechanical properties between coastal plastic waste and commercial plastic. Four types of common plastic; Polypropylene (PP), Polyethylene (PE), Polyethylene Terephthalate (PET), and Polyvinyl Chloride (PVC) are used as samples. These samples are collected, cleaned, and sorted according to type of plastics before being shredded. Then samples is melted and formed into a continuous profile via extruder and palletized into pallet-size samples. Next, samples are moulded into desired shape in accordance with American Society for Testing and Materials (ASTM) standard and tested utilizing Universal Testing Machine (UTM). From all results obtained, the mechanical properties for all type of coastal plastic wastes differ from mechanical properties of commercial plastic. This is due to the presence of salt in seawater and also direct sunlight towards the plastic waste which lead to degradation. It is recommended that other type of plastics should be used as samples and other mechanical properties should be studied in order to differentiate properties of coastal plastic waste and commercial plastic precisely.

ABSTRAK

Laut merupakan sumber utama protein dan ekonomi kepada manusia sejagat. Sejak 10 tahun yang lalu, pencemaran plastik di laut meningkat dengan mendadak dan perkara ini boleh menjejaskan kesihatan manusia, kesukaran kepada aktiviti perikanan, dan pengurangan kualiti sumber air. Bukan hanya plastik diperbuat daripada sumber yang tidak boleh diperbaharui, tetapi secara umumnya plastik merupakan bahan yang tidak terbiodegradasi atau melalui proses biodegradasi dengan sangat perlahan. Oeh itu, proses kitar semula merupakan salah satu pilihan untuk menangani isu ini. Walaubagaimanapun, disebabkan pendedahan yang lama kepada pancaran cahaya matahari dan air laut secara terus, sifat-sifat mekanik sisa plastik dari pantai ini akan berbeza berbanding plastik komersial. Objektif kajian ini adalah untuk mencirikan sifat-sifat mekanik sisa plastik dari pantai, membandingkan sifat-sifat tersebut dengan plastik komersial dan menganalisis perbezaan sifat-sifat mekanik antara sisa plastik dari pantai dengan plastik komersial. Empat jenis plastik yang biasa dijumpai dipantai; Polypropylene (PP), Polyethylene (PE), Polyethylene Terephthalate (PET), dan polyvinyl Chloride (PVC) digunakan sebagai sampel. Semua sampel dikutip, dibersihkan, dan disusun mengikut jenis sebelum dihancurkan. Kemudian sampel akan dipanaskan sehingga cair dan dibentuk menjadi pellet. Kemudian, pellet tersebut akan dibentuk mengikut piawaian yang ditentukan oleh American Society for Testing and Materials (ASTM) antarabangsa dan diuji menggunakan Universal testing Machine (UTM). Berdasarkan semua keputusan yang diperolehi, sifat-sifat mekanik untuk semua jenis sisa plastik pantai menunjukkan perbezaan daripada sifat-sifat mekanik plastik komersial. Hal ini disebabkan oleh kehadiran garam dalam air laut dan juga cahaya matahari secara langsung ke arah sisa plastik ini yang membawa kepada proses degradasi dan perubahan sifat-sifat mekanik. Dengan ini, disarankan bahawa jenis plastik yang lain harus digunakan sebagai sampel dan sifat-sifat mekanik yang lain perlu dikaji untuk membezakan sifat-sifat pantai sisa plastik dan plastik komersial dengan lebih tepat.

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%	Percentage
Σ	Summation
$\bar{X}$	Average value
R*	Free redical
H	Hydrogen
O_2	Oxygen

LIST OF ABBREVIATIONS

PP	Polypropylene
PE	Polyethylene
LDPE	Low-density Polyethylene
HDPE	High-density Polyethylene
PVC	Polyvinyl Chloride
PET	Polyethylene Terephthalate
O&G	Oil and Gas
TSS	Total suspended solids
ASTM	American Society for Testing and Materials
UTM	Universal Testing Machine
DOE	Department of the Environment Malaysia
MPa	Mega Pascal
GPa	Giga Pascal

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND OF STUDY

Malaysia's region is geographically unique and located at South East-Asia. The country is known by two lands mass; Peninsular Malaysia region and Borneo Island, which separated by South China Sea. Almost 90% of Malaysians live within 100km from seaside and approximately 70% of them stay along coastline areas. Most of them are resident of Kelantan, Terengganu, Sabah and Sarawak which are really depending on the sea for their economic sources. In general, marine is contributing almost 20% of protein for human need.

However, from past 10 years, marine pollution has extremely increased and this circumstance can threaten life of the next generation. This pollution may cause destructive consequences toward human health, complications to marine activities, and also dwindling of the quality of seawater for countless applications. 80% of the marine pollution is caused by land-based activities such as factory wastes that flow directly into the ocean, rubbish that dropped into the street washes then end up in the ocean and also the tourists and visitors themselves leave rubbish on the beach. On top of that, long-lasting plastics generally make up about 60% of rubbish and are the worst killers in the ocean. From previous research, almost 100,000 of marine mammals including dugong, dolphins, whales and turtles are killed by plastic rubbish every single year around the world.

Due to the plastic is a non-biodegradable matter, all those coastal plastic wastes should be recycled to save the earth. However, the process of recycle cannot be performed unless the mechanical properties of coastal plastic wastes are understood. This is due to the mechanical properties of coastal plastic waste which differ from commercial plastic due to presence of salt contained in the seawater and also degradation caused by direct sunlight to the plastic. Once the mechanical properties of coastal plastic wastes were found, further processes can be performed to recycle the plastic wastes.

Table 1.1: Emission of organic water pollutants

	Emissions of organic water pollutants				Industry shares of emissions of organic water pollutants							
	kilograms per day		kilograms per day per worker		Primary metals %	Paper and pulp %	Chemicals %	Food and beverages %	Stone, ceramics, and glass %	Textiles %	Wood %	Other %
	1980	1993	1980	1993	1993	1993	1993	1993	1993	1993	1993	1993
Hungary	201,888	151,311	0.15	0.18	9.9	7.6	8.1	54.9	0.2	10.8	1.8	6.8
India	1,457,474	1,441,293	0.21	0.20	15.6	8.1	7.3	50.9	0.2	12.9	0.3	4.8
Indonesia	214,010	537,142	0.22	0.19	..	7.8	10.4	58.9	0.2	15.4	4.8	2.6
Iran, Islamic Rep.	72,334	101,763	0.15	0.16	21.7	7.8	7.9	38.2	0.6	17.6	0.8	5.5
Iraq	31,805	17,882	0.18	0.15	..	15.4	16.6	43.2	0.8	18.3	0.4	5.2
Ireland	43,544	33,417	0.19	0.17	1.6	17.3	9.6	54.5	0.2	7.5	1.5	7.7
Israel	39,113	50,030	0.15	0.16	4.1	19.3	8.4	44.3	0.2	12.3	2.1	9.3
Italy	442,712	353,906	0.13	0.13	17.0	16.1	10.5	25.8	0.3	16.1	2.1	12.1
Jamaica	11,123	17,752	0.25	0.27	0.7	7.3	4.6	75.4	0.1	10.0	1.1	0.8
Japan	1,456,016	1,548,021	0.14	0.14	9.9	22.0	8.8	36.5	0.2	7.9	1.9	12.8
Jordan	4,146	11,166	0.17	0.17	4.1	15.3	15.9	49.8	0.7	7.6	3.4	3.3
Kazakhstan	..	..	..	..	..	..	..	..	..	..	..	..
Kenya	26,150	44,065	0.19	0.23	..	11.5	5.6	68.6	0.1	9.1	1.9	3.2
Korea, Dem. Rep.	..	..	..	..	..	..	..	..	..	..	..	..
Korea, Rep.	281,900	358,610	0.14	0.13	12.8	15.4	11.2	25.8	0.3	20.8	1.5	12.2
Kuwait	6,921	9,052	0.16	0.16	2.5	16.1	11.4	47.9	0.4	12.4	3.7	5.5
Kyrgyz Republic	..	25,426	..	0.19	14.2	3.0	1.1	53.5	0.5	26.1	1.5	..
Lao PDR	..	..	..	..	..	..	..	..	..	..	..	..
Latvia	..	42,866	..	0.15	2.4	7.9	5.3	57.2	0.3	14.5	3.8	8.5
Lebanon	13,137	..	0.24	..	..	..	..	..	..	..	..	..
Lesotho	190	87	0.11	0.09	..	69.5	27.6	..	2.0	..	..	0.9
Libya	3,532	..	0.21	..	..	..	..	..	..	..	..	..
Lithuania	..	..	..	..	..	..	..	..	..	..	..	..
Macedonia, FYR	..	29,054	..	0.17	16.6	8.4	6.0	37.7	0.1	24.5	2.0	4.7
Madagascar	9,196	..	0.23	..	..	..	..	..	..	..	..	..
Malawi	12,224	..	0.32	..	..	..	..	..	..	..	..	..
Malaysia	77,215	136,055	0.15	0.12	6.8	14.3	15.2	31.8	0.2	11.1	7.6	13.1
Mali	1,774	..	0.30	..	..	..	..	..	..	..	..	..

Source: World Development Indicator (1998)

1.2. PROBLEM STATEMENT

Mechanical properties of many materials especially plastics can vary depending on nature of surrounding. As plastics waste which had exposed to sea environment, it will tend to have some differences in term of mechanical properties compared to standard commercial plastics. Due to almost all types of plastic are made of non-renewable resources and environmental concern, all the coastal plastic wastes should be recycled. However, in order to recycle all those coastal plastic wastes and reproduce new commercial plastics, the mechanical properties of coastal plastic wastes should be investigated so that the recycling process can be done effectively.

1.3. OBJECTIVE OF RESEARCH

The main point of view of this study is to transform the unusable coastal plastic waste into valuable new recycled product by studying the mechanical properties of coastal plastic waste. As regards to this point of view, there are three objectives of this research which are:

i. To characterize mechanical properties of coastal plastic waste,
ii. To compare the mechanical properties of coastal plastic waste with the commercial plastic.
iii. To analyse the differences of mechanical properties between coastal plastic waste and commercial plastic.

1.4. RATIONALE AND SIGNIFICANCE OF STUDY

Marine pollution especially caused by plastic matters is getting higher. Plastics are non-biodegradable materials and it will tend to have special mechanical properties once it submerged in seawater for a period of time. The mechanical properties of coastal plastic wastes should be different from commercial plastic thus causing inconvenience in carrying out the process of recycling. Therefore, this study will be conducted in order to characterize the mechanical properties of coastal plastic wastes. Once the data of mechanical properties of coastal plastic wastes can be obtained, further processes for recycling plastic waste can be performed very well.

1.5. RESEARCH QUESTION

i. Are the mechanical properties of coastal plastic waste can be determined?
ii. Are there any differences in term of mechanical properties between coastal plastic waste and also commercial plastic?

1.6. SCOPE OF RESEARCH

In order to achieve the objectives, these following scopes have been identify and to applied:

i. The sample which is plastic waste will be collected at beaches around Kuantan, Pahang.
ii. Selected type of plastic will be used to characterize the coastal plastic wastes which are Polypropylene (PP), Poly Vinyl Chloride (PVC), Polyethylene (PE), and Polyethylene Terephthalate (PET),
iii. The only mechanical properties that being studied for selected plastic types are Modulus of Elasticity, Tensile Strength and also Percentage of Elongation.

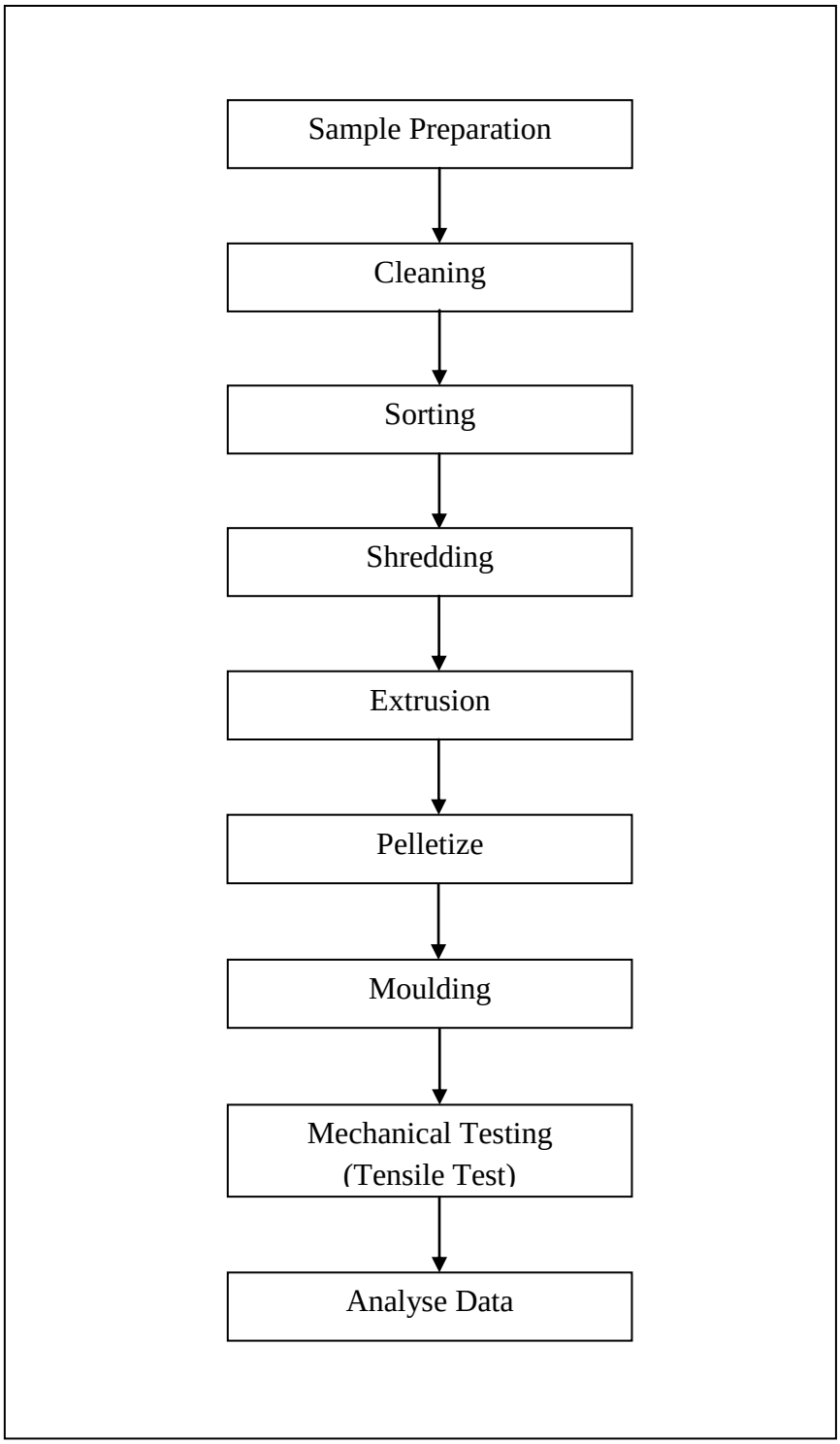

Figure 1.1: Experimental workflow

CHAPTER 2

LITERATURE REVIEW

2.1. MARINE POLLUTION

Marine pollution can be defined as the introduction by man, directly, or indirectly, of substances or energy to the marine environment. This pollution may result in harmful effects towards human health, difficulties to marine activities, and also deterioration of the quality of seawater for various uses. From previous study, 80% of the marine pollution is caused by land-based sources. Domestic wastes and sewage, including solid and liquid wastes are major pollutants of coastal waste. Some of the sources come from rubbish that dropped in the street washes into drains ends up in the ocean and factory wastes that flow directly into the ocean without any systematic waste management. Marine pollution also caused by humans' activities on the oceans for examples kitchen boat waste, discharged and by accidently lost fishing nets and floats (Henry, 2011).

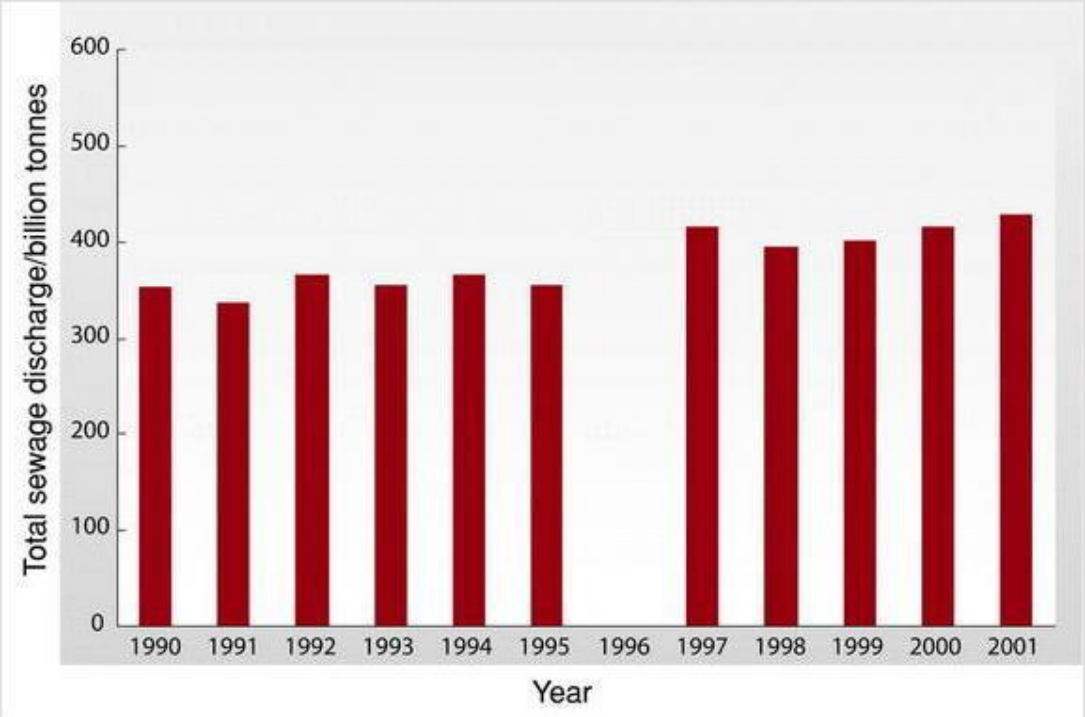

Figure 2.1: Ocean pollution from land-based activities

Source: http://www.csa.com

According to Department of The Environment Malaysia (DOE), from 1999 to 2004, they found that marine pollution had beyond the standard sea water quality recommended, especially for such parameters of oil and grease (O&G), total suspended solid (TSS), and also coliform bacteria (E.coli). Oil spills from oil tankers or during ship cleaning process have contributed to the increasing of O&G parameter. Meanwhile, most of the parameter of TSS and E.Coli contaminants caused by development activities in coastal areas such as construction, industrial activities, and also livestock activities. According to Cho and Kadaruddin (1997), construction of tourist attraction centres in the coastal environment has negative impacts towards marine pollution and the potential for beach erosion.

Table 2.1: The average concentration of O&G, TSS, E.Coli and Heavy Metal in sea water, Malaysia for 1999 – 2004

Pollutant	Standard Sea Water Quality Recommended	1999	2000	2001	2002	2003	2004
O&G	0 mg/l	2.46	1.00	0.85	0.94	0.95	1.20
TSS	50 mg/l	108	108	174	118	153	139
E.Coli	100MPN/100ml	41643	79693	39739	48594	24127	14276
Copper	0.1 mg/l	0.036	0.031	0.042	0.049	0.065	0.056
Mercury	0.001 mg/l	0.001	0.002	0.001	0.001	0.003	0.001
Lead	0.1 mg/l	0.015	0.045	0.042	0.042	0.134	0.162
Cadmium	0.1 mg/l	0.002	0.003	0.004	0.007	0.019	0.029
Arsenic, mg/l			0.1	0.002	0.003	0.017	0.002
Chromium, mg/l			0.5	0.034	0.009	0.036	0.039

Source: Department of the Environment Malaysia (2005)

Table 2.2: PVC waste per end-use category, aggregated, in Kilo tonne

	Year			
Waste Type	1998	2000	2005	2010
Agricultural	28	29	28	25
Building	1026	1070	1366	1660
Packaging	692	644	585	589
Industry	89	98	115	141
Automotive	180	195	208	216
TOTAL	2015	2036	2302	2606

Source: Tukker *et al* (1999)

2.2 PLASTIC

Plastic also known as polymer is a gigantic molecule which composed of repeating units called monomer. The term monomer refers to small molecules or atoms that have chemical bonding to form polymer (Callister, 2008). This means polymer is large molecules consist of repeating unit of monomer bind together via interatomic bond. For example, polybutadiene is a common polymer consist of monomer called 1,3-butadiene.

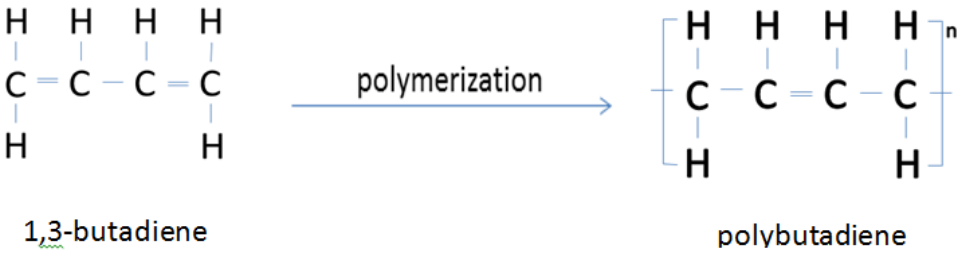

Figure 2.2: Polymerization of 1,3-butadiene

There are two subdivisions of plastics which are thermoplastic and also thermosetting. Thermoplastic is a linear polymer (single chain of monomer) and also branched polymer (linear polymer with side chain) and it softens when heated. While thermosetting is a cross-linked polymer (two or more linear polymer joined by side chain) and it hardens when heated.

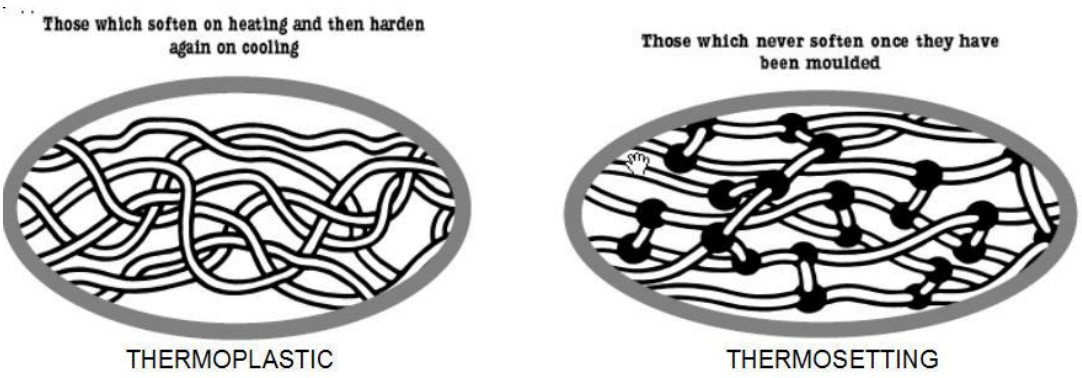

Figure 2.3: Differences between thermoplastic and thermosetting

Source: http://tecnoelpalo.wikispaces.com

There are millions of types of polymer that exist in the whole world. However, only four types of polymer will be analyzed to make comparison in term of mechanical properties. They are Polyethylene (PE), Polypropylene (PP), Polyethylene Terephthalate (PET) and also Polyvinyl Chloride (PVC).

2.2.1. Polyethylene (PE)

Polyethylene is a polymer with an ethylene monomer as repeating units. Polyethylene is one of the thermoplastic polymers. There are two types of Polyethylene; High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE). LDPE regularly used in plastic bags, cling film, and flexible containers. Meanwhile, HDPE usually used in production of automotive fuel tank bottles, toys, and also piping system due to it much more stronger and more rigid, as well as being more dense and higher-melting rather than LDPE.

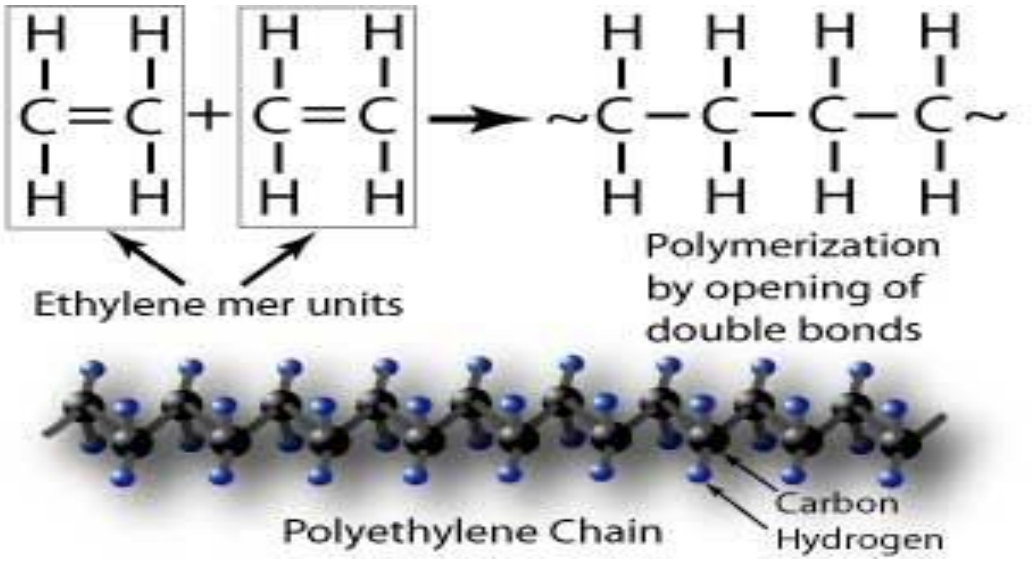

Figure 2.4: Polymerization of Polyethylene

Source: http://www.ndt-ed.org

There are some of mechanical properties of commercial Polyethylene as shown in Table 2.3.

Table 2.3: Mechanical Properties of Polyethylene

	Value	Unit
Modulus of Elasticity		GPa
• LDPE	0.282	
• HDPE	1.08	
Poisson's Ratio		
• LDPE	0.4	
• HDPE	0.46	
Yield Strength		MPa
• LDPE	14.5	
• HDPE	26.2	
Tensile Strength		MPa
• LDPE	31.4	
• HDPE	31.0	
Percent Elongation		%
• LDPE	100	
• HDPE	10	

Source: Callister (2008)

2.2.2. Polypropylene (PP)

Polypropylene is a thermoplastic polymer with propylene monomer as repeating units. Propylene is used in wide variety of application, including food containers, battery cases, automotive parts, bottle crates and also fibres. Polypropylene exists in two types which are homopolymer and also co-polymer grade. Monopolymer is a polymer with just one repating monomer while copolymer is made of different type of monomers. Copolymer polypropylene is less strong and less stiffness rather than homopolymer polypropylene. However, copolymer polypropylene is tougher and more durable than homopolymer polypropylene.

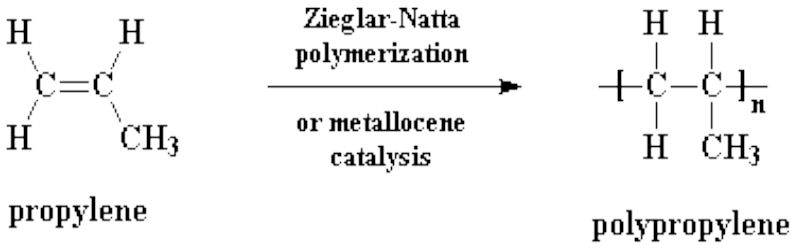

Figure 2.5: Polymerization of Polypropylene

Source: http://www.pslc.ws

Commercial Polypropylene has its own mechanical properties as follows:

Table 2.4: Mechanical Properties of Polypropylene

	Value	Unit
Modulus of Elasticity	1.55	GPa
Poisson's Ratio	0.40	
Yield Strength	37.2	MPa
Tensile Strength	41.1	MPa
Percent Elongation	100	%

Source: Callister (2008)

2.2.3. Polyethylene Terephthalate (PET)

Polyethylene Terephthalate is a polymer consists of polymerized units of the monomer called ethylene terephthalate, with repeating unit of $C_{10}H_8O_4$. Polyethylene terephthalate is a thermoplastic polymer, which is in solid structure at room temperature. However, it can flow if it is heated above its glass transition temperature and become solid again when cooled. Polystyrene is widely used in production of dairy product containers, cups, plates, packaging trays, and also moulding compound.

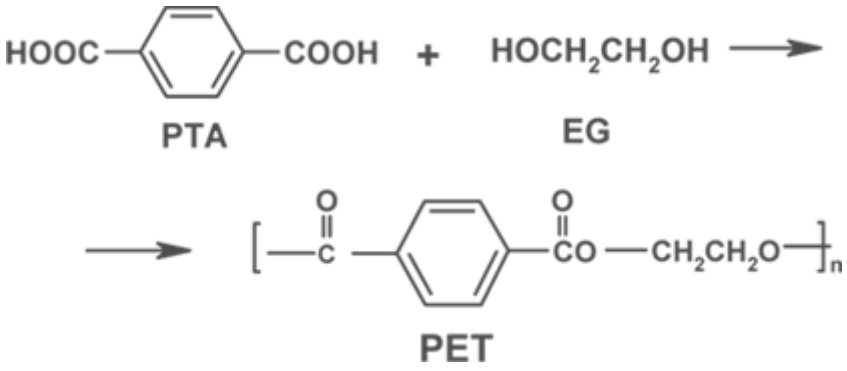

Figure 2.6: Polymerization of Polyethylene Terephthalate

Source: http://www.pslc.ws

There are some of mechanical properties of commercial Polyethylene Terephthalate as follows:

Table 2.5: Mechanical Properties of Polyethylene Terephthalate

	Value	Unit
Modulus of Elasticity	2.80	GPa
Poisson's Ratio	0.44	
Tensile Strength	80.00	MPa
Percent Elongation	60.00	%

Source: Callister (2008)

2.2.4. Polyvinyl Chloride (PVC)

Polyvinyl Chloride is a common polymer constructed of repeating unit of ethenyls monomer but one of the hydrogen branches is replaced by chloride group. Polyvinyl Chloride is one of thermoplastic polymer which commonly used in manufacture of flooring, window frames, packaging films, cable insulation, medical products and also credits cards.